An analysis on the potential of a global energy crisis in our lifetimes

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Structure:
Part I: The Status Quo of energy production and consumption
Part II: The 3 possibilities of outcomes for the near future and their ramifications
Part III: The potential solutions and their likelihoods

Part I: The Status Quo of energy production and consumption

Our contemporary human global industrial civilization has been made possible, and is entirely dependent on, the exploration, extraction, and consumption of non-renewable fossil fuels such as coal, oil, and gas. Books such as *Energy and civilization: a history by Vaclav Smil* and *Energy and the Wealth of Nations: An introduction to Biophysical Economics by Charles Hall and Kent Klitgaard* document this statement historically and extensively. Recent reports such as the *World Energy Outlook 2019*[1] *& 2020*[2] *by the International Energy Agency* document the energy sector in a more near-term timeframe.

Of the fossil fuels available to us, crude oil provides the most energy-dense non-nuclear fuels for our every-day civilizational needs[2a]. And our consumption of it keeps increasing decade after decade (Figure 1) to fuel our economic growth as well as our population growth (Figure 1a).

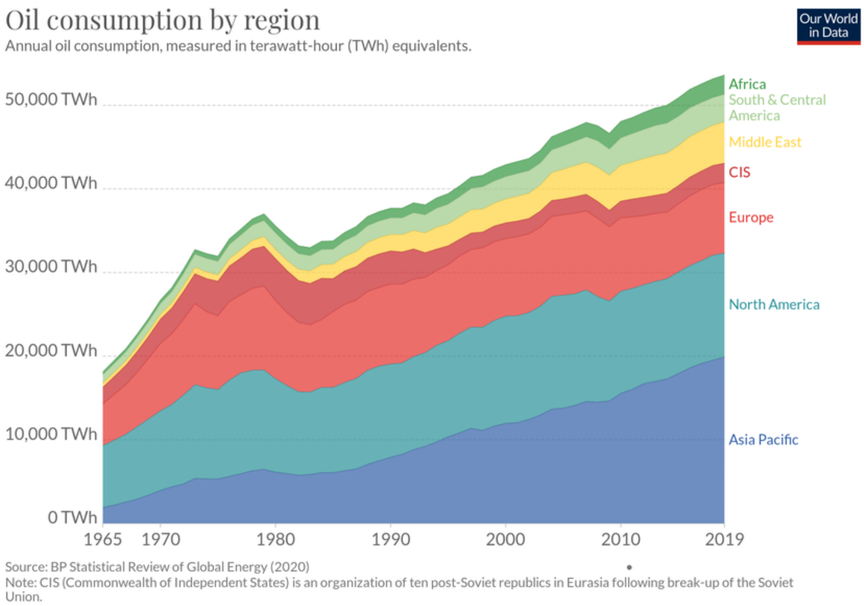

Figure 1: *Oil consumption by region, 1965-2019*

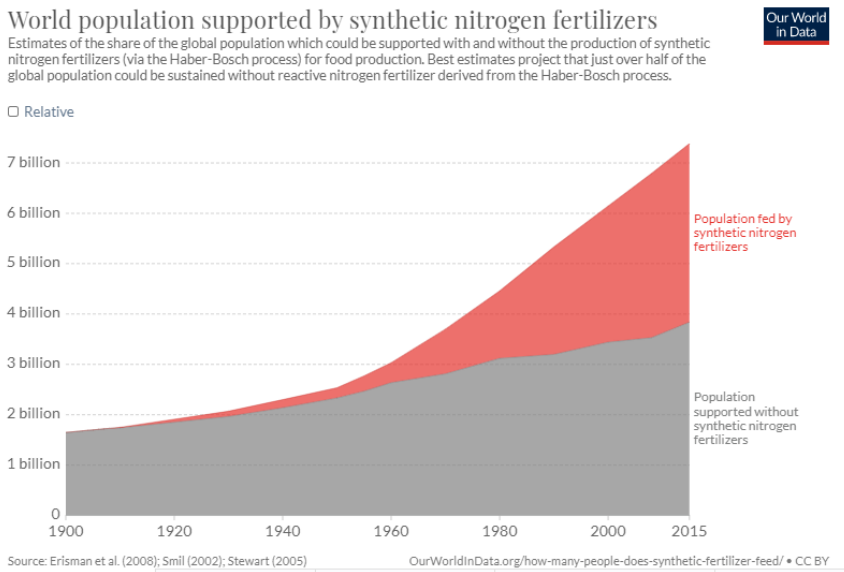

Figure 1a: *World population supported by synthetic nitrogen fertilizers, 1900-2015*

At the same time, our existing reserves of such an important resource are being depleted, faster than we are producing them, reducing the buffer we have. Consider, for example, the reserves to production ratio for the major "Big Oil" companies in the last decade (Figure 2):

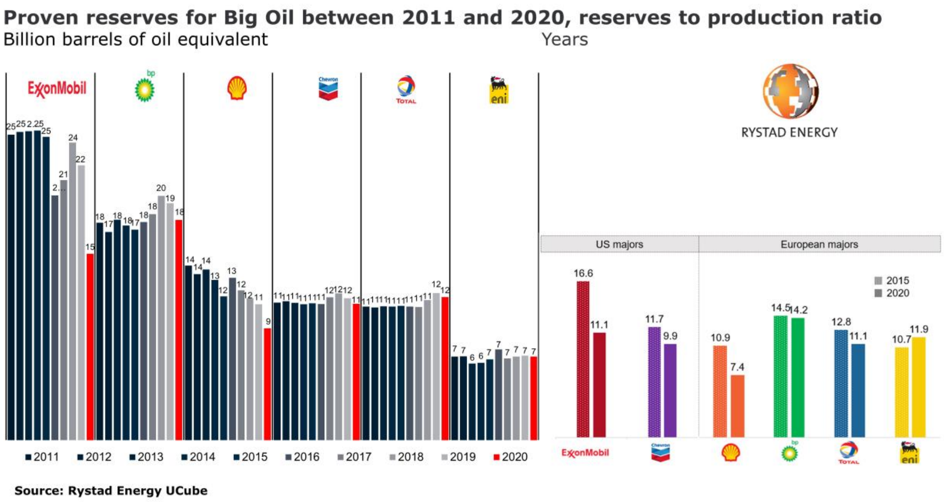

Figure 2: *Proven reserves for Big Oil, reserves to production ratio, 2011-2020*

Proven reserves[2b], in comparison to probable and possible reserves, comprise the vast majority of all reserves. They are geologically verified and have a > 90% probability to actually contain the estimated amount of oil. Probable reserves (> 50%) and possible reserves (> 10%) are much more speculative. Because the amount of oil that can be extracted depends on the current oil price, their effective size changes drastically with new information (see Figure 2a)

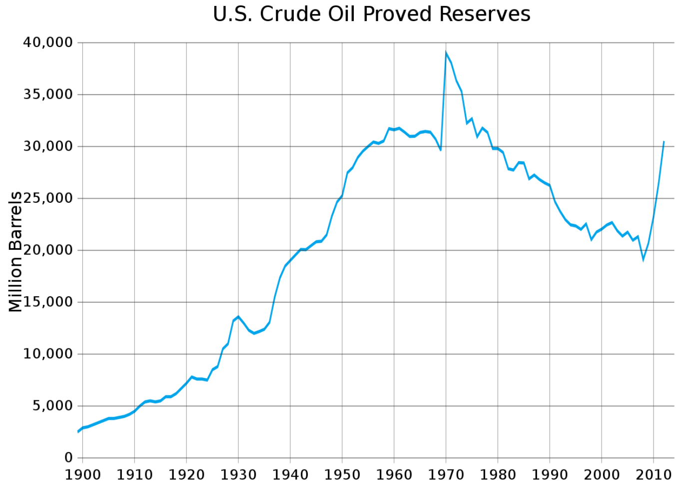

Figure 2a: *U.S. Crude Oil Proved Reserves (Million Barrels) 1900-2014*

In the industry, there is a fairly well-known discovery shortfall for new sources of profitable oil, with overall oil discoveries at their lowest in 65 years[3] (Figure 3), and conventional oil and gas discoveries at a 70 year low[4].

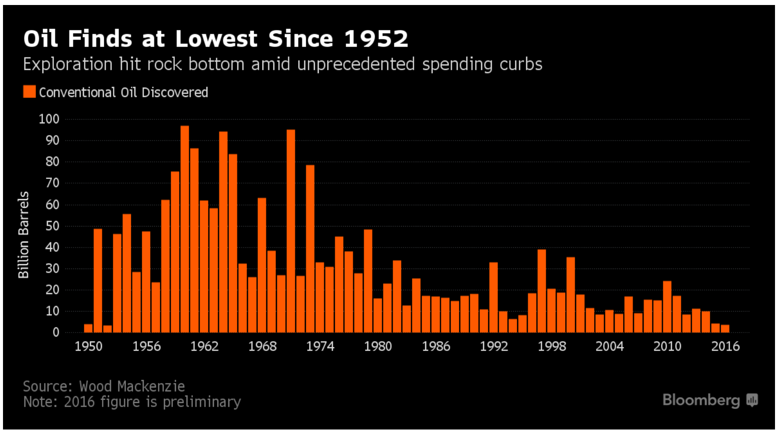

Figure 3: *Oil Finds at lowest since 1952, 1952-2016*

Fueled by past trends[5,5a] and the impact of the coronavirus pandemic[6], the first reputable energy analysts (WoodMackenzie, Rystad Energy, Bloomberg) have started sounding the alarms over the near-term depletion of oil and its consequences to the fossil fuel-dependent society we have built around it. More recently, Shell has changed their usual optimistic tune and started expecting a future reduction in oil production[6a].

However, there are more factors yet still to consider. For example, the climate implications of certain types of fossil fuel emissions, or the quantities of emission. Considering what we know in terms of emissions and climate impact, data such as the one presented in Figure 4 signals to the energy industry that around ⅔ of their available reserves should not be extracted and used, due to the negative impacts they would cause in our world.

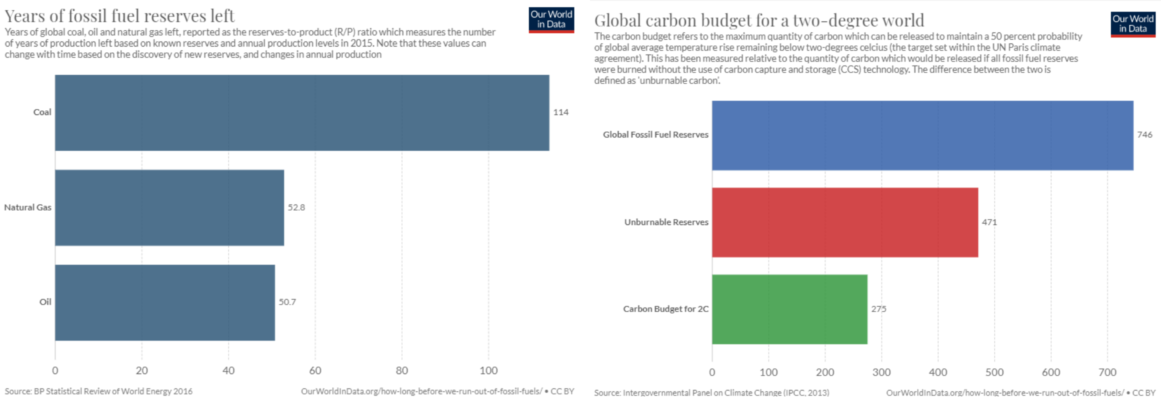

Figure 4: *Years of fossil fuel reserves left, and Global carbon budget for a two-degree world*

Another factor is that there are still plenty of fossil fuel sources available for extraction, but they are unprofitable to explore until a certain market price is reached. Venezuela, with their hard-to-extract bituminous oil sands, is becoming a poster child for this[7]. Nominally, the state has proven reserves of 300 billion barrels, but only 6 billion might be ultimately recoverable. More generally, oil production in the countries with the most promising reserves seem to be struggling already. Russia, one of the top 3 oil producers[7a], already seems to be in systemic production decline[8], Venezuela is continuing a steady decline in production[9], and Canada is struggling with high extraction costs[10].

Consider Figure 5, where we seemingly have reserves worth trillions of barrels of oil available to explore, however each subsequent type of oil reserve demands a considerably increased cost of extraction.

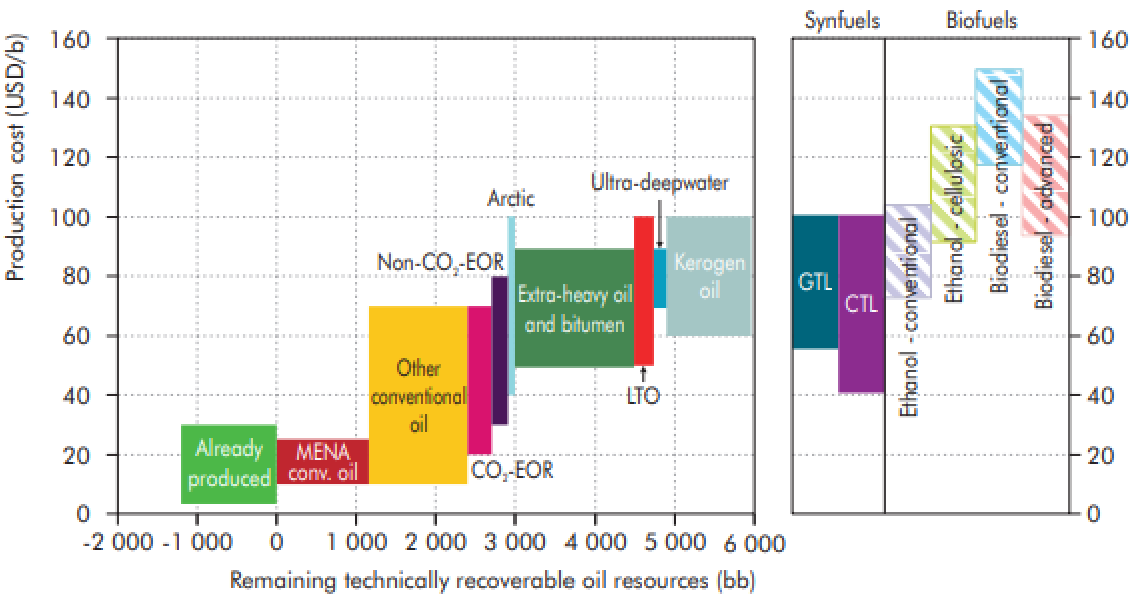

Figure 5: *Oil production costs for various resource categories*

This connection between market price and overall accessible amount of oil is such a strong link that proven reserves change drastically from year to year, when prices rise or drop (e.g. “Exxon Mobil's total reserves drop by a third after COVID-19 oil price drop”[11]).

An average price of $40/bbl cuts off the extraction of half of the conventional reserves, and blocks the extraction of heavy oil fields outright (See Figure 5a):

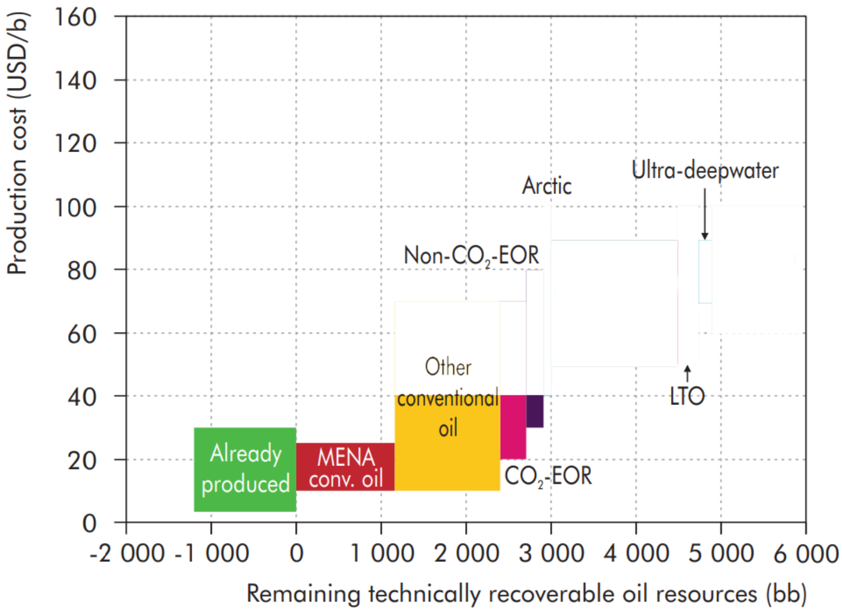

Figure 5a: *Reserves available under a $40 barrel of oil price, adjusted from Figure 5*

Furthermore, lower oil prices mean that there's less profit margin left over to invest into exploring future oil fields (i.e. exploration). The period 2015-2019 has been shaped by unusually low oil prices, leading to the current shortfall in explored fields.

Historically, the market price of oil, once inflation-adjusted, has been relatively stable with two notable exceptions in the 1970s and 2000s, seen in Figure 6 and Figure 7:

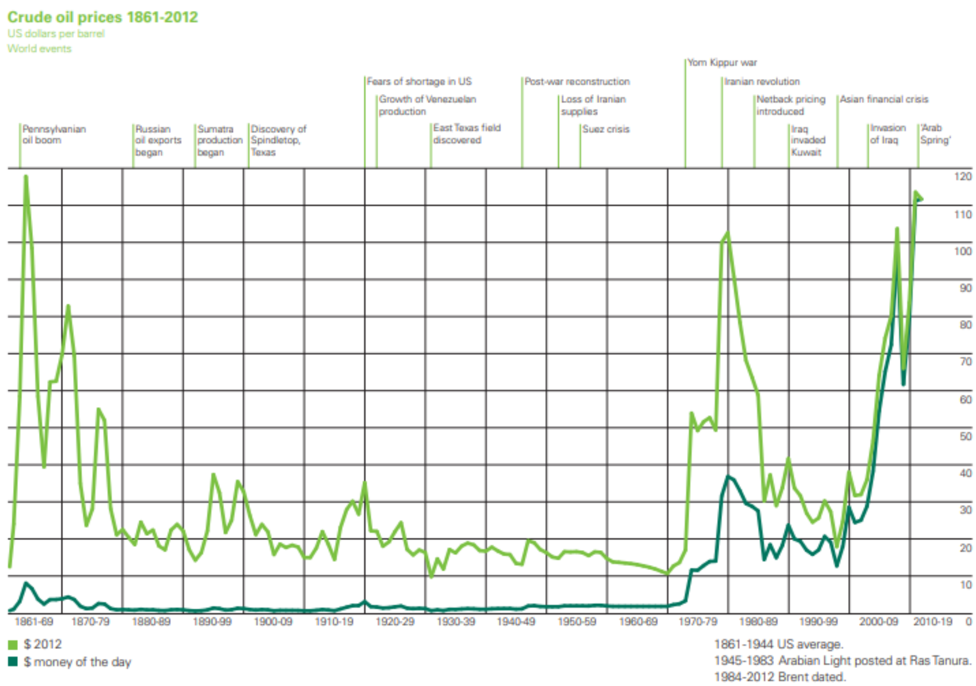

Figure 6: *Crude oil prices, 1861-2012*

Historically speaking, we can see that the inflation-adjusted price of oil rarely exceeds $40 per barrel. The three exceptions to that rule are arguably major anomalies (1. initial oil boom phase, 2. oil crisis of 1973, 3. great financial crisis) that should not indicate a stable trend.

The most recent price developments seem to imply that the long-term average oil price will return below an inflation-adjusted $40/bbl. This goes against conventional wisdom in the industry, where prices are always assumed to rise in response to depleting supply.
If reality follows this common wisdom, oil prices will rise continuously and progressively unlock more and more oil fields, until all reserves are suddenly depleted in the year 2068[12]. That progression would be very unusual, compared to the historical production curves of other depleted energy resources. Those (e.g. hard coal in Germany, British forests) usually take the shape of a hill distribution. Assuming that oil follows a similar production curve, we should realistically expect a production peak way before 2068 and a quick decline after that.

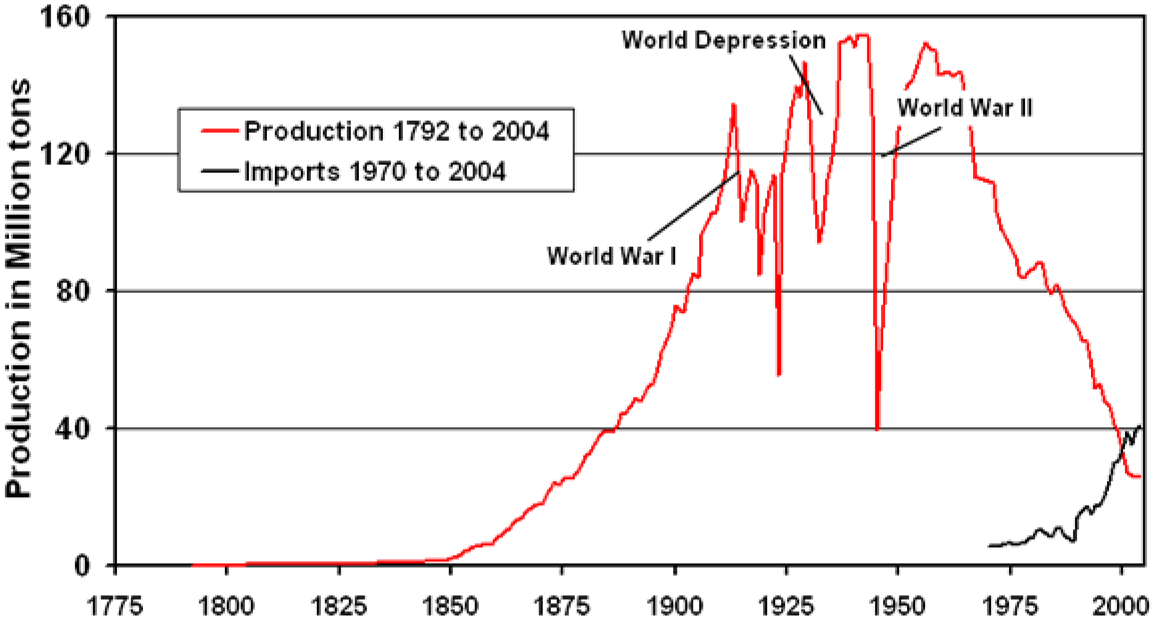

Figure 7: Historical *production curve of hard coal in Germany (production stopped completely in 2018)*

That said, even the assumption of ever-rising prices should be called into question.
This is a difficult discussion to lead, because there are only very flimsy arguments in favor of endlessly rising prices. The proponents usually point to the demand/supply curve taught in basic economics: in an ideal and steady-state market, declining supply is met with rising prices. It's questionable how accurate this model is for depleting energy resources without replacement. However, the historical price development of oil (Figure 8) doesn't seem to be in line with a long-term rising trend - at least not when adjusting for inflation.

Figure 8: *Crude Oil Prices: WTI, 1990-2021, inflation-adjusted to 2013 dollars*

Whereas the price hike leading up to the 2008 financial crisis could have been explained by the limited reserves starting to be priced in by the market, the price drop in 2014 is disconnected from any large-scale financial movements. This hints at previous spikes having been overvalued, and prompting a return towards the historical average/median value.

A	B	C	D	E	F
Year	Daily BOE World oil Consumption	Billion BOE Consumed/ Year	Billion BOE Oil discovered	BOE Oil Shortfall	Consumed times greater than found
2013	92,276,000	32.8	8.1	24.7	4.0
2014	93,194,000	33.3	7.56	25.8	4.4
2015	95,048,000	34.7	5.85	28.85	5.9
2016	96,737,000	35.3	4.27	31.03	8.3
2017	98,406,000	35.9	6.9	29	5.2
2018	99,843,000	36.4	5.6	30.8	6.5
2019	100,100,000	36.5	4.76	31.74	7.7

Figure 9: *Recent and rising depletion rate of oil reserves (2013-2019)*

With proven reserves currently depleting 7.7 times faster (see Figure 9) than we are “replenishing” them through exploration, the remaining reserves are on a terminal trend. If we assume that no new cheap oil fields are going to be found in the near future, existing reserves are going to run out much sooner than the year 2068. Depending on its inflation-adjusted market price of oil, we foresee 3 main scenarios to that depletion rate.

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